# Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/GB05/001035

International filing date: 17 March 2005 (17.03.2005)

Document type: Certified copy of priority document

Document details: Country/Office: GB
Number: 0406079.4
Filing date: 18 March 2004 (18.03.2004)

Date of receipt at the International Bureau: 26 July 2005 (26.07.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

PCT/GB2005/001035

INVESTOR IN PEOPLE

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed

Dated 17 May 2005

**Patents Form 1/77**

[redacted] Act 1977
[redacted])

# 1/77

The Patent Office

## Request for grant of a patent

THE PATENT OFFICE
C
18 MAR 2004
NEWPORT

**The Patent Office**

Cardiff Road
Newport
South Wales
NP10 8QQ

1. Your reference — **2040-P~~153-GB~~**

18 MAR 2004

2. Patent application number *(The Patent Office will fill this part in)* — **0406079.4**

18MAR04 E881963-1 D03028
P01/7700 0.00-0406079.4 ACCOUNT CHA

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

**ELEKSEN LIMITED**
**Charter Court**
**Midland Road**
**Hemel Hempstead**
**Hertfordshire HP2 5GE**
**United Kingdom**

Patents ADP number *(if you know it)* — 828892001

If the applicant is a corporate body, give the country/state of its incorporation — **United Kingdom**

4. Title of the invention — **SENSOR RESPONSE**

5. Name of your agent *(if you have one)* — **ATKINSON BURRINGTON**

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

**28 President Buildings**
**President Way**
**Sheffield**
**S4 7UR**

Patents ADP number — **7807043001**

6. Priority: Complete this section if you are declaring priority from one or more earlier patent applications, filed in the last 12 months.

| Country | Priority application number *(if you know it)* | Date of filing *(day / month / year)* |
|---|---|---|
| **N/A** | **N/A** | **N/A** |

7. Divisionals, etc: Complete this section only if this application is a divisional application or resulted from an entitlement dispute.

| Number of earlier application | Date of filing *(day / month / year)* |
|---|---|
| **N/A** | **N/A** |

8. Is a Patents Form 7/77 (Statement of inventorship and of right to grant of a patent) required in support of this request? — **YES**

Answer YES if:
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
Otherwise answer NO

9. Accompanying documents: A patent application must include a description of the invention. Not counting duplicates, please enter the number of pages of each item accompanying this form:

| | |
|---|---|
| Continuation sheets of this form | 00 |
| Description | 28 |
| Claim(s) | 02 |
| Abstract | 00 |
| Drawing(s) | 21 + 2 RM |

10. If you are also filing any of the following, state how many against each item.

| | |
|---|---|
| Priority documents | N/A |
| Translations of priority documents | N/A |
| Statement of inventorship and right to grant of a patent *(Patents Form 7/77)* | NONE |
| Request for preliminary examination and search *(Patents Form 9/77)* | ONE |
| Request for substantive examination *(Patents Form 10/77)* | NONE |
| Any other documents *(please specify)* | NONE |

11. I/We request the grant of a patent on the basis of this application.

Signature(s) Date **Wednesday, 17 March 2004**

12. Name, daytime telephone number and email address, if any, of person to contact in the United Kingdom — **RALPH ATKINSON CPA 0114 275 2400**

CT-03-105

# Sensor Response

## Background of the Invention

### 1. Field of the Invention

The present invention relates to control of the response of a sensor, in particular to the control of the sensitivity of a position sensor comprising a plurality of conductive textile layers.

### 2. Description of the Related Art

For many applications of touch sensors, the sensor is required to be flexible and highly sensitive to applied pressure. A type of three-layer fabric touch sensor comprises two outer conductive textile layers and a central partially insulating separator layer defining a plurality of apertures. The separator layer is configured to space the conductive textile layers apart when no pressure is applied to the sensor, and to allow electrical contact between the layers therethrough during a mechanical interaction. By varying the size of the apertures in the separator layer, the sensitivity of the sensor can be manipulated to allow electrical contact between the conductive layers when pressure above a predetermined threshold is applied to the sensor.

A problem with this type of textile sensor, however, is undesirable electrical contact, or triggering, resulting from internal forces, for example as a result of bending or flexing of the sensor. US patent publication 4,659,873 discloses a sensor comprising two outer conductive textile layers and a

central insulating separator layer, and the layers are stretched across a frame such that the layers are held flat across the apertures of the separator layer. However, this arrangement is not suitable for applications of touch sensors in which flexibility is required.

A further problem with this type of textile sensor is uneven response to applied pressure for example, certain locations within the sensing area may be more sensitive than other locations. International patent publication WO 00/072239, assigned to the present applicant, describes a type of five-layer textile sensor, the sensor providing suitable sensitivity and resistance to undesirable triggering. The cost of production of this more complex sensor, however, is considered to diminish the range of realistic commercial applications of the sensor.

It is thus desirable to provide a sensor that is flexible, displays uniform sensitivity and is economical to manufacture.

**Brief Summary of the Invention**

According to a first aspect of the present invention there is provided a sensor comprising a first conductive knitted textile layer, a second conductive textile layer and a central partially insulating separator layer disposed therebetween, said central separator layer defining a plurality of apertures, wherein the natural radius of yarn within said first conductive knitted layer fits within an aperture.

According to a second aspect of the present invention there is

provided a sensor comprising a first conductive knitted textile layer, a second conductive textile layer and a central partially insulating separator layer disposed therebetween, said central separator layer defining a plurality of apertures, wherein the stitch size of yarn within said first conductive knitted layer is smaller in at least one dimension than the aperture diameter size of said separator layer.

**Brief Description of the Several Views of the Drawings**

*Figure 1* shows an exploded view of a flexible position sensor;

*Figure 2* illustrates the structure of the partially insulating separator layer identified in *Figure 1*;

*Figure 3* shows a cross-section of a detector;

*Figure 4* shows a graph of trigger pressure plotted against mesh density;

*Figure 5* shows an assembled flexible position sensor;

*Figure 6* shows an exploded view of a keypad;

*Figure 7* shows a cross-section of the keypad of *Figure 6*;

*Figure 8* shows the effects of the key shown in *Figure 7* being pressed at a position displaced from its ideal central location;

*Figure 9* shows a mesh with extension portions;

*Figure 10* illustrates properties for a detector using the mesh shown in *Figure 9*;

*Figure 11* shows a three-layer position detector;

*Figure 12* shows a typical compliant fabric;

*Figure 13* shows a second typical compliant fabric;

*Figure 14* shows a compliant knit entering through a hole defined in a partially insulating mesh;

*Figure 15* shows results obtained by using compliant layers;

*Figure 16* shows a keypad;

*Figure 17* shows an alternative detector;

*Figures 18-21* each show a three-layer sensor;

*Figure 22* shows a cross-section of the sensor of *Figure 21*;

*Figure 23* shows a typical response of a three-layer sensor having a construction incorporating a dimensional relationship between stitches in conducting layers and apertures in the separator layer; and

*Figure 24* shows layers of a three-layer sensor;

*Figure 25* shows different yarns.

## Written Description of the Best Mode for Carrying Out the Invention

### *Figure 1*

An exploded view of a flexible position sensor is shown in *Figure 1*, consisting of a first electrically conducting layer **101**, a second electrically conducting layer **102** and a partially insulating mesh **103** separating the first layer **101** from the second layer **102**.

The electrically conducting layers are preferably in the form of fabrics machined from a mixture of electrically conducting fibres and insulating fibres. An example of a fabric of this type is disclosed in International Patent Publication No. WO 00/72240 assigned to the present applicant.

A current may flow in the first plane **101** in a direction indicated by arrow **104** in response to an electrical potential applied between conducting members **105** and **106**. Similarly, a current may flow in the second conducting layer **102** in a direction indicated by arrow **107** in response to a voltage being applied across conducting members **108** and **109**.

***Figure 2***

Insulating mesh **103** is formed from knitted monofilament yarns or alternatively a moulded plastic and as such provides a regular mesh structure **201**, as illustrated in *Figure 2*.

In known position detectors, the mesh material **202** would have a typical thickness of 0.09 mm. This thin mesh defines an arrangement of holes. In a uniform mesh, an important property that affects performance is the area of the holes. In a regular mesh configuration, such as that illustrated in *Figure 2*, a similar property may be identified in terms of the effective hole area and measurements may be taken from materials to determine their effective or average hole area.

In order to be sensitive to manual interaction, the detector must be sensitive to relatively low pressures. Experiments have shown that the

detector becomes more sensitive as the mesh thickness is decreased and/or the effective hole area is increased. Thus, in this example, with a mesh thickness of 0.09 mm, an effective hole area of 3.8 $mm^2$ allows the detector to be fabricated that is sufficiently sensitive. However, a problem with this approach is that such a mesh is likely to allow false triggering of the device, particularly if it is subject to a modest degree of flexing. False triggering may also occur due to undulations in the detector or in a cover layer.

***Figure 3***

A cross section of a detector is shown in *Figure 3*. A first conducting layer **301** is separated from a second conducting layer **302** by a mesh **303**. When pressure is manually applied, the conducting layers are brought together, as illustrated at location **304**.

When applying pressure as illustrated in *Figure 3*, an average finger would cover an area of approximately **100** $mm^2$. For most applications, such as when being used as a keypad a user would be comfortable when applying a force of 0.5 newton to 1 newton, resulting in an applied pressure of five kPa (kPa) to ten kPa. The mesh previously described, having a mesh thickness of 0.09 mm and an effective hole area of 3.8 $mm^2$ operates under these conditions. However, a three layer detector fabricated from a mesh of this type will also be sensitive to false triggering therefore it does not provide a satisfactory configuration for many applications.

The position sensor may be provided with an appropriate concentration device for localising the area of application of an applied force to thereby increase the pressure applied to the detector. The inclusion of an appropriate force concentration device allows the mesh thickness to be increased and/or the hole size to be reduced. In this way, the combination of the concentration device with a denser mesh structure ensures that the device is sufficiently sensitive to tactile mechanical interactions while at the same time it is substantially more resilient against false triggering caused by flexing the device.

Experiments have shown that meshes with similar mesh densities have similar properties in terms of their level of sensitivity. Thus, it is not the absolute mesh thickness or the absolute hole area that determines the properties of the detector. It is the ratio between these two quantities therefore, for the purposes of this disclosure, a mesh density parameter may be defined as the mesh thickness divided by the effective hole area.

***Figure 4***

Experiments have shown that, to a significant degree of accuracy, the level of pressure required in order to cause triggering varies with mesh density. A graph of trigger pressure plotted against mesh density is shown in *Figure 4*. The shaded region **401** represents mesh densities that have been used in known detectors. They are sufficiently sensitive for direct manual operation but are also sensitive to false triggering. The shaded

region **402** represents detectors having a mesh density ranging from 0.**045** to 0.1. Mesh density is increased such that a pressure of between 50 kPa to **100** kPa is required in order to trigger the detector. This enhanced pressure is obtained by the provision of an appropriate concentration device for localising the area of the applied force.

A known partially insulating mesh that is susceptible to false triggering has a mesh thickness of 0.09 mm and an average hole area of 3.8 mm$^2$. This provides a mesh with a mesh density of 0.23 requiring a trigger pressure of ten kPa. This example of a known mesh is illustrated by line **403** in *Figure 4*. As can be seen from *Figure 4*, line **403** lies within region **401**, confirming that a mesh with these characteristics is susceptible to the false triggering condition.

***Figure 5***

An assembled flexible position sensor is shown in *Figure 5*. The first electrically conducting layer has been covered by a protective layer **501**. A force concentration device is provided in the form of a stylus **502**. The stylus **502** has a stylus tip **503** such that force applied to the stylus during manual operation by a user results in this force being concentrated at the tip **503** of the stylus **502**. In this way, it is possible for the position of the mechanical interaction to be detected through the relatively dense mesh of the device without substantial force being required from the user.

As described in European Patent Publication No. EP 0 **989 509**

(P**106**) assigned to the present Applicant, the detector is configured to detect positions of mechanical interaction upon the protective layer **501** in addition to detecting an extent of the mechanical interaction. Thus, positional information (x and y) is obtained in combination with extent (z) information. This information is determined by circuitry **504** and conveyed to processing equipment over an interface **505**.

***Figure 6***

The flexible position sensor may also be used as part of a flexible keypad. The keypad may be used to supply alphanumeric characters to a hand held processing device, as disclosed in International Patent Publication No. WO 01/75572 assigned to the present applicant. The keypad shown in *Figure 6* is shown in an exploded view.

An upper fabric layer **601** has a similar construction and texture to a substrate **602**. The upper fabric layer **401** has alphanumeric characters **603** printed thereon and the position of these characters aligns with raised key defining positions **604** in a silicone rubber layer **605**. In addition to the raised key defining positions, the silicone rubber key defining layer also includes support regions **606** that contact the position detector and thereby hold the assembly in place.

The position detector as used in the keyboard again consists of a first conducting layer **607**, a partially insulating mesh layer **608** and a second conducting layer **609**. Alternatively, a five layer construction could

be used as described in Patent Publication No WO 00/72239.

***Figure 7***

A cross section of the keypad shown in *Figure 6* is shown in *Figure 7*. The fabric layer **601** has been bonded to the silicone rubber layer **602**. The total width of a defined key is approximately 17 mm as illustrated by arrow **701**. The key positions include an upper portion **702** having an upper surface **703** and a lower surface **704**. The upper surface **703** supports the application of a finger and to assist in this operation, the upper surface **703** presents a slightly concave profile to the approaching finger.

A contact position **706** extends from the lower surface **504** to the upper portion **702** and as such provides a force concentration device for localising the area of application of an applied force. When not under pressure, the contact portion **706** is displaced from the position detector by a displacement of preferably 0.2 mm, as illustrated by arrow **507**. In alternative embodiments, this distance may be changed to displacements of say, between zero and 0.8 mm. A displacement of between 0.1 and 0.3 mm is considered to be preferred.

Wall portions **708** extend between support region **709** and the upper portion **702**. The wall portions under region **709** of the upper portion surrounding the contact portion **706** have a reduced thickness. The reduced thickness is provided so as to enhance collapsibility when a finger press is displaced from its preferred central location.

***Figure 8***

The effects of the key shown in *Figure 7* being pressed at a position displaced from its ideal central location is illustrated in *Figure 8*. Finger pressure is applied in a direction identified by arrow **801**, that is offset from an optimum central position of the upper portion **702** as identified by arrow **802**. Under these conditions, a near wall portion **803** collapses and the upper portion **702** rotates as illustrated by arrow **804**, with respect to a far wall portion **805**. As this rotation takes place, the contact position **706** applies contact force to the sensor over a contact region **807**.

In a preferred embodiment, the contact portion **707** has a substantially spherical profile and were the whole sphere to be present, such a sphere would have a radius of typically 4 mm to 10 mm and would preferably have a radius of 5 mm. In a preferred embodiment, the virtual radius of this contact portion is optimised so as to provide an optimised contact area **807** such that intentional key presses are detected and un-intentional false triggering is minimised.

Thus, the spherical profile of the contact portion provides a force concentration device for localising the area of application of the applied force. This allows greater resilience to false triggering by reducing the hole area. This tendency is also enhanced by the provision of a thicker mesh. In order to compensate for the reduction in hole size, the size of the concentrating device may be reduced. That is to say, the virtual radius of

the contact portion may be reduced.

In an example detector, the mesh is provided with a mesh thickness of 0.09 mm and an effective hole area of 2 $mm^2$. A mesh of this type therefore has a mesh density of 0.045. Thus, it should be appreciated that the hole area has approximately been halved thereby almost doubling the mesh density when compared to the previously described known mesh.

In a further example, a detector is fabricated using a mesh with a thickness of 0.19 mm and an effective hole are of 3.1 $mm^2$. In this detector, the mesh density is therefore 0.06. Contact area **807** shown in *Figure 8* measures approximately 10 $mm^2$ when a key has been pressed with a force of between 0.5 newton and 1 newton. The resulting pressure on the detector therefore ranges from fifty kPa to one hundred kPa and this is more than sufficient to cause contact between the conductive layers through a mesh having a mesh density between 0.**045** $mm/mm^2$ and 0.1 $mm/mm^2$.

***Figure 9***

In addition to having a high mesh density, the mesh may also have extension portions **911** extending from extension positions **912** upon the mesh. Preferably, these extension portions occur at positions of mesh intersection. The provision of the extensions further displaces the first conducting layer from the second conducting layer.

The provision of extension portions further separates the first

conducting layer from the second conducting layer so as to further reduce the occurrence of false triggering. The provision of these extension portions is particularly effective at reducing the occurrences of false triggering caused by undulations or creases in the sensor or cover. However, the area of mesh covered by these extension portions is relatively small therefore they do not add significantly to the actual thickness of the mesh over the majority of the mesh surface. Consequently, the additional resistance provided to intentional mechanical interactions is minimal. Thus, the provision of the extension portions reduces the extent of false triggering while at the same time providing little further resistance to intended layer interaction.

A mesh of this type, having extension portions included thereon, is available from Applied Extrusion Technologies Limited, Bristol, England. The extension portions are referred to as bosses and the material may be defined in terms of the mesh thickness and the boss count.

An example of an appropriate product is sold under the trademark Delnet X550. This is fabricated from an extruded and embossed high density polyethylene. The material has a weight of 12 gms per square metre and a thickness of 0.11 mm. Typically, it has a boss count of 8.3 in a first direction and 9.4 per cm in an orthogonal direction.

An alternative product is sold under the trademark Delnet X220. Again, the material is extruded and embossed from high density polyethylene and has a weight of 27 gms per square meter. It is 0.26 mm

thick and has a boss count of 4.3 per cm length.

An alternative material is sold under the trademark Delnet X215. The material is of similar construction having a weight of 34 gms per square meter, a thickness of 0.25 mm and a boss count of 5.5 per linear cm.

***Figure 10***

As described with respect to *Figure 4*, the inclusion of a force concentrating device allows the mesh density of the partially insulating mesh to be increased up to a value of 0.1. This provides a useful operating range of mesh densities ranging from 0.045 to 0.1 requiring a range of trigger pressures from 50 kilopascal (kPa) to 100 kPa. The results obtained when using a mesh that has extension portions, as described with respect to *Figure 9*, is illustrated in *Figure 10.* In addition to operating region **402**, a device fabricated using the type of mesh illustrated with respect to *Figure 10* provides an additional operating region **1001**. Thus, in this example, the mesh density may be increased to 0.2 for a similar trigger pressure.

***Figure 11***

*Figure 11* shows a position detector **1101** comprising two outer conducting textile layers **1102**, **1103** and a central partially insulating separator layer **1104**. The conducting layers **1102, 1103** of the position detector are of a woven fabric construction. Fabrics of this type have good conducting properties but they do not stretch or compress significantly. In

order for conduction to take place, the fabric must buckle up in order to enter a gap in the separator layer so as to contact with its opposing conducting layer on the other side of the partially insulating layer. When pressure is applied to the woven fabric layer, the fabric is placed in lateral tension, in the X and Y directions along the sheet. Standard woven textiles are not extensible in the lateral direction. In order for electrical contact to be made between the conducting layers **1102**, **1103**, the fabric must gather up under the applied pressure. This construction renders the sensor relatively insensitive to applied pressure. To compensate, the thickness of the separator layer may be reduced, however, this results in the sensor being prone to undesirable electrical contact, or false triggering, due to internal forces. Another characteristic of this type of sensor is that the response to applied pressure is dependent upon the compliance of the actuator applying the pressure. The actuator should be sufficiently compliant in the z-axis to locally deform a conductive layer into an aperture of the separator layer. In practice, if the actuator is pointed the applied pressure may result in only a single contact, the fabric being forced into one aperture only. Alternatively, pressure is applied over a broader area, resulting in multiple contacts through multiple holes in the separator layer. An actuator having a hard, flat surface requires a greater degree of force to be used to establish an electrical contact than an actuator having a soft, compliant surface. This property may be modified by the incorporation of an additional layer, on top or underneath the sensor, which is compliant in the z-axis. The additional

layer may be a fabric or a foam layer.

***Figure 12***

Conducting layers are fabricated with a degree of compliance thereby ensuring the fabrics ability to be forced through holes of the partially insulating layer. In this way, sensitivity to intended contact may be enhanced and/or the thickness of the mesh may be increased in order to reduce unintentional triggering.

A typical compliant fabric is shown in *Figure 12*, taking the form of a knitted fabric in preference to a woven fabric. The fabric consists of yarns **1201** that are knitted and as such meander, thereby allowing them to easily extend in the direction of the plane or in the direction perpendicular to the plane, the latter facilitating hole entry. It can be seen from *Figure 12* that each yarn of the weft knit construction, for example yarn **1202**, loops underneath another, forming a lower looping portion that protrudes in the z-axis from the lower surface of the fabric. Similarly, upper looping portions protrude from the upper surface of the fabric. It can be seen that in the looping portion, the yarn reverses direction, i.e. changes direction through at least 180 degrees. In addition, each loop has a natural radius in the at rest condition, indicated in region **1203**.

***Figure 13***

A typical knitted fabric of warp knit construction is shown in *Figure 13.* This fabric construction also comprises looping portions. It is to be appreciated that the degree to which a looping portion protrudes is dependent upon the specific fabric knit construction.

***Figure 14***

The ability of a compliant knit **1401** to enter through a hole **1402** defined in a partially insulating mesh **1403** is illustrated in *Figure 14*. Force applied to the compliant fibre in the direction of arrow **1404** results in the fabric being received within hole **1402**.

Preferably, the compliant conducting layers take the form of a very fine warp knit. A pitch between stitches are between 0.1 mm to 0.3 mm provides a smooth uniform surface, free from bumps and lumps.

Preferably, the warp knit construction incorporates a substantially equal mix of conducting yarns with insulating yarns.

In an alternative configuration, a woven fabric is constructed using yarns with significant inherent elasticity. Thus, the compliance may be provided by the elasticity of the yarn itself or, alternatively, a non elastic yarn may be used to produce a warp knit fabric such that the degree of compliance is provided by the nature of the fabricated material.

A further degree of compliance may be achieved by providing a degree of compressibility to the separating partially insulating mesh. Thus, the provision of a compliant conducting layer and/or a compliant central layer

ensures that there is a sensitive response to pressure while at the same time minimising false triggering due to bending or flexing.

***Figure 15***

The results obtained by using compliant layers is illustrated in *Figure 15*. If present embodiments of the present invention are not used, known detectors require a mesh with a mesh density less than 0.04 mm/mm$^2$. Such meshes lie within region **401** and as such, unless solely used stretched across a frame, are susceptible to false triggering.

As previously described, higher mesh densities, up to a density of 0.1 mm/mm$^2$ may be used if used in combination with the force concentrating device. In this way, useful devices may be produced with mesh densities between 0.045 and 0.1 mm/mm$^2$, lying within region **402**.

Further enhancements may be obtained by the inclusion of extension portions as previously described. Without any additional pressure being required, the mesh density may be increased to 0.2 mm/mm$^2$ as represented by additional region **1501**. By the inclusion of compliant fabrics mesh density may be further increased, typically to 0.3 mm/mm$^2$ thereby extending the useful region to include region **1501** as shown in *Figure 15*.

***Figure 16***

The inclusion of these enhanced techniques as described herein allow a three layer detector to be used within a manually operable keypad, such as

keypad **1601** shown in *Figure 16*. Optimal operation is obtained with higher mesh densities and preferably with mesh densities of between 0.2 and 0.23 $mm/mm^2$. Each key position, such as key position **1602**, includes a device for concentrating the force when applied to the detector layers. In this way, it is possible to increase the mesh density. Mesh density is increased further by the provision of extension portions upon the mesh itself. Additional mesh density increase is then provided by introducing compliance to the layers of the detector. In particular, the conducting layers are allowed to stretch thereby facilitating the entry of conducting layers within holes of the conducting mesh. In addition, the conducting mesh itself is made compressible so as to reduce the distance through which the conducting layers must pass.

***Figure 17***

An alternative detector is shown in *Figure 17*. The detector **1701** is constructed from fabric layers as previously described. However, the detector is configured so as to be responsive to direct manual pressure applied by a user's finger. Furthermore, the detector is configured such that it provides position data at a high definition substantially throughout the plane. Thus, from the user's perspective, the detector is perceived as providing analogue data in the x and y dimensions. Consequently, it is not possible to provide key locations. Thus, there is no possibility of providing force enhancing devices either in the form of a stylus or in the form of protrusions for the underside of

keys. However, it is still desirable to provide an appropriate degree of sensitivity to manual pressure while at the same time minimising false triggering.

With fabric detectors, false triggering tends to occur due to the presence of creases and folds in the material. The regions therefore tend to be spread out in a linear fashion whereas intended mechanical interactions take the form of more regular contact areas, that is to say, they are substantially two-dimensional.

In order to provide an appropriate level of sensitivity for the detector shown in *Figure 16*, an insulating mesh, similar to mesh **103**, has a mesh density less than 0.04 $mm/mm^2$. However, the mesh is provided with extension portions as illustrated in *Figure 9*. Thus, the provision of extension portions extending from extension positions of the mesh displace the first conducting layer from the second conducting layer so as to minimise the occurrence of false triggering.

A detector of this type may alternatively, or in addition, be provided with compliant conducting layers so as to enhance the false triggering characteristics. Thus, a device of this type may embody the use of extension portions and/or may embody the use of compliant materials. However, in order to provide a substantially analogue response, a mesh density is adopted such that it is not necessary to use force concentrating devices.

***Figure 18***

*Figure 18* shows a three-layer sensor **1801** in which the outer conductive layers **1802**, **1803** are of a weft-knit construction. Within the assembly, intersections of the central partially insulating separator layer **1804** are adjacent looping portions of each conductive knitted layer. The sensor in *Figure 18* is shown in the no pressure applied condition. In this example, the thickness of each conductive layer **1802**, **1803** is approximately half the thickness of the separator layer **1804**.

***Figure 19***

*Figure 19* shows a three-layer sensor **1901** in which the outer conductive layers **1902**, **1903** are of a weft-knit construction, and within the assembly, looping portions of each conductive knitted layer are adjacent supporting elements of the central partially insulating separator layer **1904**. The sensor in *Figure 18* is shown in the pressure applied condition, with arrow **1905** indicating the direction of the applied pressure at a location between supporting portions of the central partially insulating separator layer **1904**. With the shown in-phase alignment of looping portions and supporting elements, the applied pressure is insufficient to bring the outer conductive layers **1902**, **1903** into electrical contact.

***Figure 20***

*Figure 20* shows a three-layer sensor **2001** in which the outer conductive layers **2002**, **2003** are of a weft-knit construction, and within the assembly, looping portions of each conductive knitted layer are in between supporting elements of the central partially insulating separator layer **2004**. Thus, in the no pressure applied condition the outer conductive layers **2002**, **2003** of sensor **2001** are closer together than the outer conductive layers **1902**, **1903** of sensor **1901** in the same condition. The sensor in *Figure 20* is shown in the pressure applied condition, with arrow **2005** indicating the direction of the applied pressure at a location between supporting portions of the central partially insulating separator layer **2004**. With the shown out-of-phase alignment of looping portions and supporting elements, the applied pressure is sufficient to bring the outer conductive layers **2002**, **2003** into electrical contact.

Thus, a sensor having this construction may display non-uniform sensitivity across the sensing area thereof; displaying a lesser degree of sensitivity at locations where the looping portions are in-phase with supporting elements, or intersections, and displaying a greater degree of sensitivity at locations where the looping portions are out-of-phase with supporting elements, or intersections, of the separator layer. Such a sensor may be impractical in use, unless the least sensitive zones display the minimum useful operational sensitivity. For example, in finger touch sensing applications, if the sensitivity of the sensor is selected to respond to an

average value within a predicted applied pressure range, mechanical interactions within "dead" regions of the sensor may be insufficient to trigger a response, therefore missed inputs may occur.

For the sensor to be useful, the sensitivity, which can be varied by varying the thickness and/or aperture size of the separator layer, is therefore selected to display the minimum useful operational sensitivity within the least sensitive regions. This, however, creates regions having a much higher sensitivity, resulting in effectively oversensitive "hotspot" zones highly prone to undesirable electrical contact, or false triggering, for example in response to bending or flexing.

***Figure 21***

*Figure 21* shows a three-layer sensor **2101**, having two outer knitted conductive layers **2102**, **2103** and a central partially insulating separator layer **2104**. It can be seen that with the shown construction, false triggering results from contact between the outer layer at the point on the bend corresponding to an out-of-phase portion.

***Figure 22***

*Figure 22* shows a cross-section of a three-layer sensor **2201**, the construction of which incorporates a dimensional relationship between the stitches of the outer knitted conductive layers **2202**, **2203** and the apertures

of the separator layer **2204**. The stitches in the conductive layers **2202, 2203** are substantially smaller in at least one dimension, for example in stitch length or pitch, than the aperture diameter size of the separator layer **2204** measured in the same corresponding direction. It is to be appreciated that in variant embodiments the apertures of the separator layer may be any shape or different shapes and therefore the term aperture diameter size is used to indicate linear distance across an aperture measured in the same direction as the measurement of stitch dimension.

With this construction provides at least one looping portion fits in each aperture, in effect, providing an out-of-phase alignment of looping portions and supporting elements, or intersections, of the separator layer **2204** throughout the sensor.

Arrow **2205** represents stitch length of fabric layer **2202** and arrow **2206** represents aperture diameter size of separator layer **2204**. It is clearly shown in *Figure 22* that these measurements are taken in the same direction as each other. As can be seen from *Figure 22*, the stitch length **2205** is substantially smaller than the aperture diameter size **2206**. In the shown arrangement, at least one looping portion of each outer conductive layers **2202, 2203** fits in each aperture in the separator layer **2204**.

***Figure 23***

*Figure 23* shows a typical response of a sensor having a construction incorporating the dimensional relationship described with reference to *Figure 22* under applied pressure. Three-layer sensor **2301** comprises two outer conductive textile layers **2302**, **2303** and a central partially insulating separator layer **2304**. Sensor **2301** is shown in the pressure applied condition, with arrow **2305** indicating the direction of pressure applied to conductive layer **2302** at a location between supporting portions of the central partially insulating separator layer **2304**. With the shown out-of-phase alignment of looping portions and supporting elements, the applied pressure is sufficient to bring outer conductive layer **2302**, into electrical contact with outer conductive layer **2303**.

The uniformity of sensitivity of the sensor is improved by at least one looping portion of a conductive layer being situated wholly within an aperture of the separator layer, throughout the sensing area. Thus, the uniformity of the response of the sensor to applied pressure is improved. In effect this arrangement smoothes out the "dead" zones and "hotspot" zones of a sensor. When a suitable mesh is selected to control the overall sensitivity of the sensor, the sensor displays a greater immunity to undesired electrical contact, or false triggering, for example as a result of bending or flexing the sensor.

As previously described, within a looping portion, the yarn reverses direction, i.e. changes direction through at least 180 degrees. With the

arrangement shown in *Figure 23,* the radius of a loop is tighter than that of the apertures in the separator layer **2304**. Thus, the yarn has a natural radius that fits within an aperture.

## *Figure 24*

*Figure 24* illustrates the layers within a three-layer sensor **2401**, the construction of which incorporates a dimensional relationship between the stitches of the outer conductive layers **2402**, **2403** and the apertures of the separator layer **2404**. In this example, the apertures in separator layer **2104** have an aperture diameter size substantially larger than the stitch length or pitch of the conductive layers **2402**, **2403,** along substantially perpendicular axes.

In this example, both conductive textile layers **2402**, **2403** are cut from the same textile having a repeating pattern construction throughout. In addition, the aperture shape and pattern of central separator layer **2404** is regular. Arrow **2405** represents a first dimension of stitches in conductive layer **2402** in the indicated Y axis, and arrow **2406** represents the aperture diameter size of apertures in separator layer **2404** along the Y axis. Arrow **2407** represents a second dimension of stitches in conductive layer **2403** in the indicated X axis, and arrow **2408** represents the aperture diameter size of apertures in separator layer **2404** along the X axis. This construction, in effect, provides an out-of-phase alignment of looping portions and supporting

elements, or intersections, of the separator layer **2404** throughout sensor **2401**, and provides a plurality of looping portions in each aperture.

In addition, the natural radius of yarn in each of the conductive layers **2402, 2403** fits within the apertures of central separator layer **2404**.

***Figure 25***

The uniformity of response of a sensor may be improved by the utilisation of compliant yarns within the construction of the conductive textile layers of the sensor. *Figure 25* shows three yarns **2501**, **2502** and **2503**. First non-compliant yarn **2501** is a monofilament yarn, whereas first compliant yarn **2502** is a multifilament yarn. Multifilament yarns have a degree of inherent compliance, however, the compliance thereof can be improved by the inclusion of elastic yarns, for example Lycra TM or Elastane TM. First compliant yarn **2502** is an untwisted multifilament yarn, however multifilament yarns are typically twisted, and the twisted type of multifilament yarn is considered to provide an equal or improved performance.

Second compliant yarn **2503** is a textured yarn. Such yarns are typically used to provide additional softness and compliance to enhance the feel of a fabric. Different processes may be used to produce textured yarn including processes utilising air jets during yarn cooling, or processes in which twisting, heating and untwisting of a multifilament yarn is performed. Irrespective of the manufacture process, the textured yarn is “fluffy”. The additional compliance introduced by using textured yarn in the conductive

layers provides a more controlled collapse of the layers under applied pressure. This further improves the uniformity of sensitivity, and provides a sufficiently sensitive response, of the sensor, particularly in response to applied pressure.

A practical application for such a three-layer sensor is a strip sensor used with a chair having a motorised moving component mechanism. The sensor is attached to the leading edge of the moving component, which may be located on the underside of the motorised chair, and is configured to provide input data to the motor control of the moving component mechanism. This arrangement provides a safety function to prevent the mechanism closing on an obstacle, such as an animal or a child. In a safety mode of operation, the sensor detects an obstacle in the path of the moving component and the motor control responds to stop movement of the moving component continuing in the same direction, to prevent crushing or trapping of the obstacle.

## Claims

**1.** A sensor comprising a first conductive knitted textile layer, a second conductive textile layer and a central partially insulating separator layer disposed therebetween, said central separator layer defining a plurality of apertures, wherein the natural radius of yarn within said first conductive knitted layer fits within an aperture.

**2.** A sensor comprising a first conductive knitted textile layer, a second conductive textile layer and a central partially insulating separator layer disposed therebetween, said central separator layer defining a plurality of apertures, wherein the stitch size of yarn within said first conductive knitted layer is smaller in at least one dimension than the aperture diameter size of said separator layer.

**3.** A sensor according to claim **1** or claim **2** in which said conductive knitted layer has a warp knit or weft knit construction.

**4.** A sensor according to claim **1** or claim **2** in which a conductive textile layer has a woven construction.

**5.** A sensor according to any preceding claim comprising a conductive textile layer including textured yarn.

**6.** A sensor according to any preceding claim comprising a conductive textile layer including elastic yarn.

**7.** A sensor according to any preceding claim in which said central separator layer is compressible under manually applied pressure.

**8.** A sensor according to any preceding claim comprising a conductive textile layer having a thickness greater than half the thickness of the central separator layer.

**9.** A sensor substantially as herein described with reference to and as shown in *Figures 22 to 25* of the accompanying drawings.

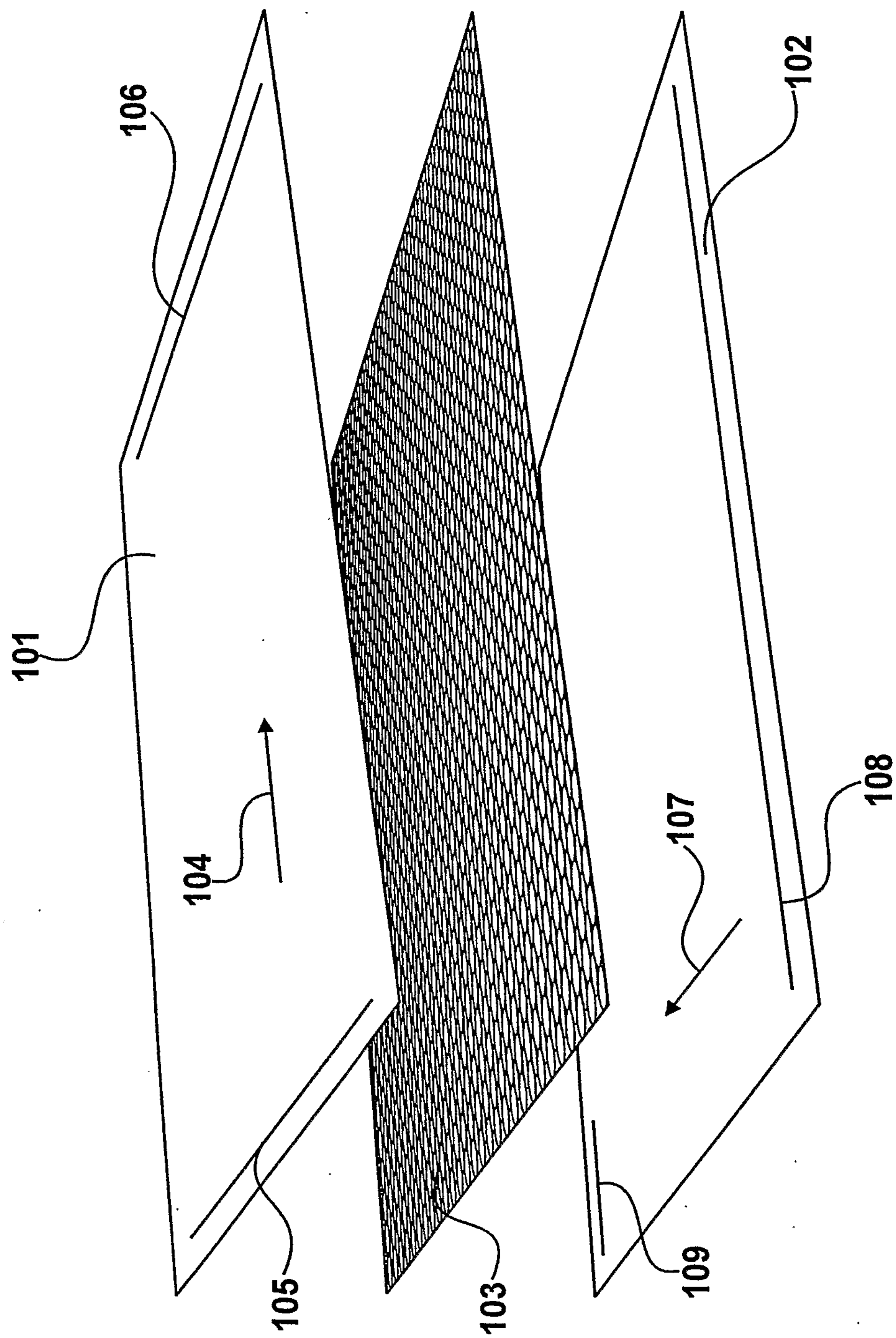



Figure 1

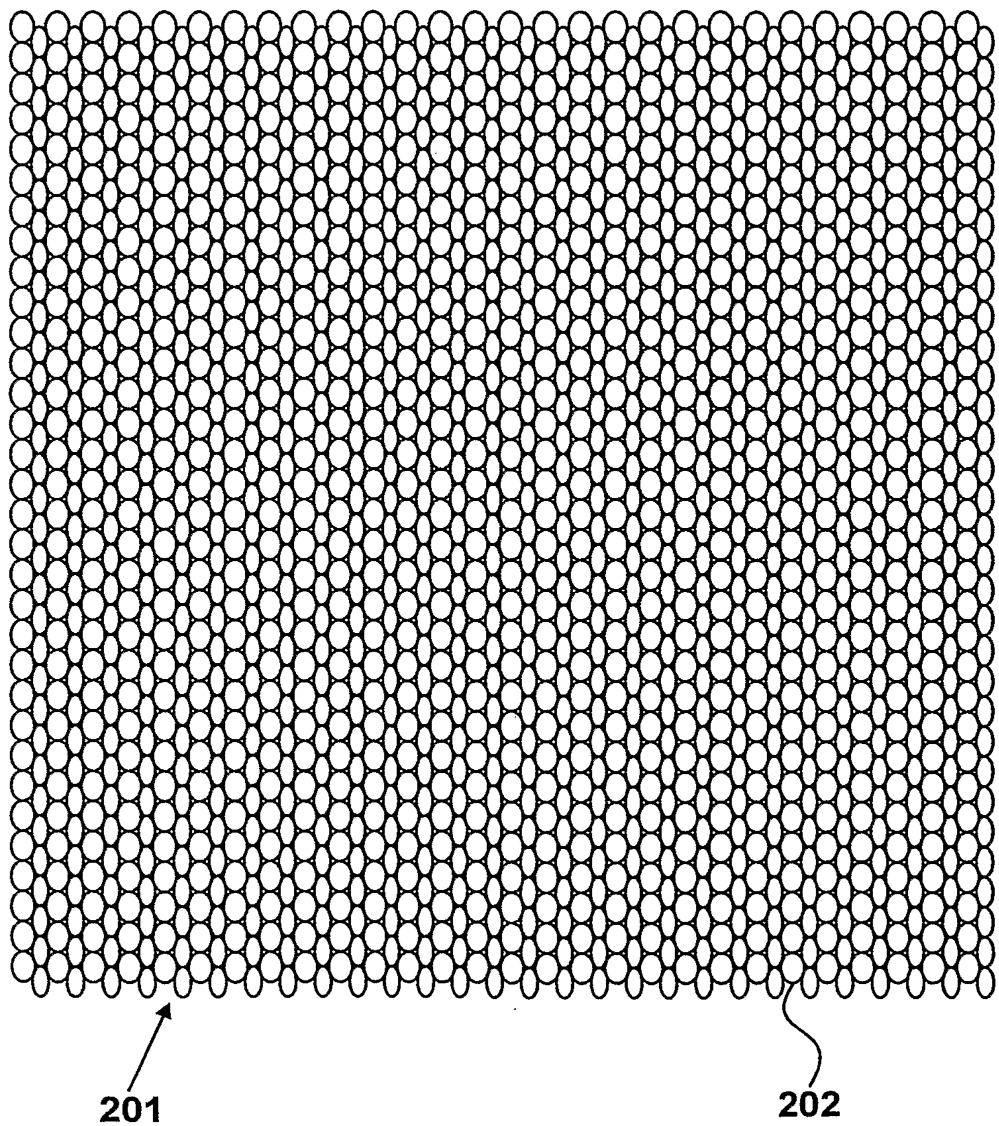



Figure 2

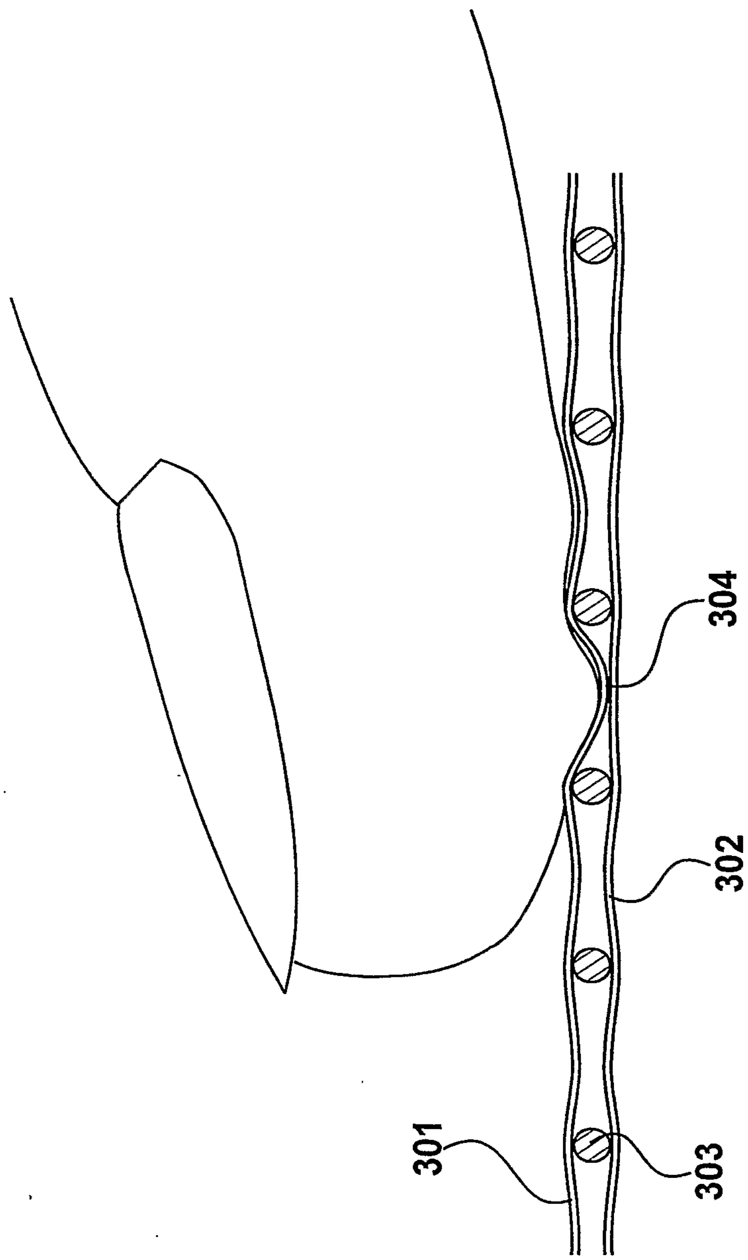



Figure 3

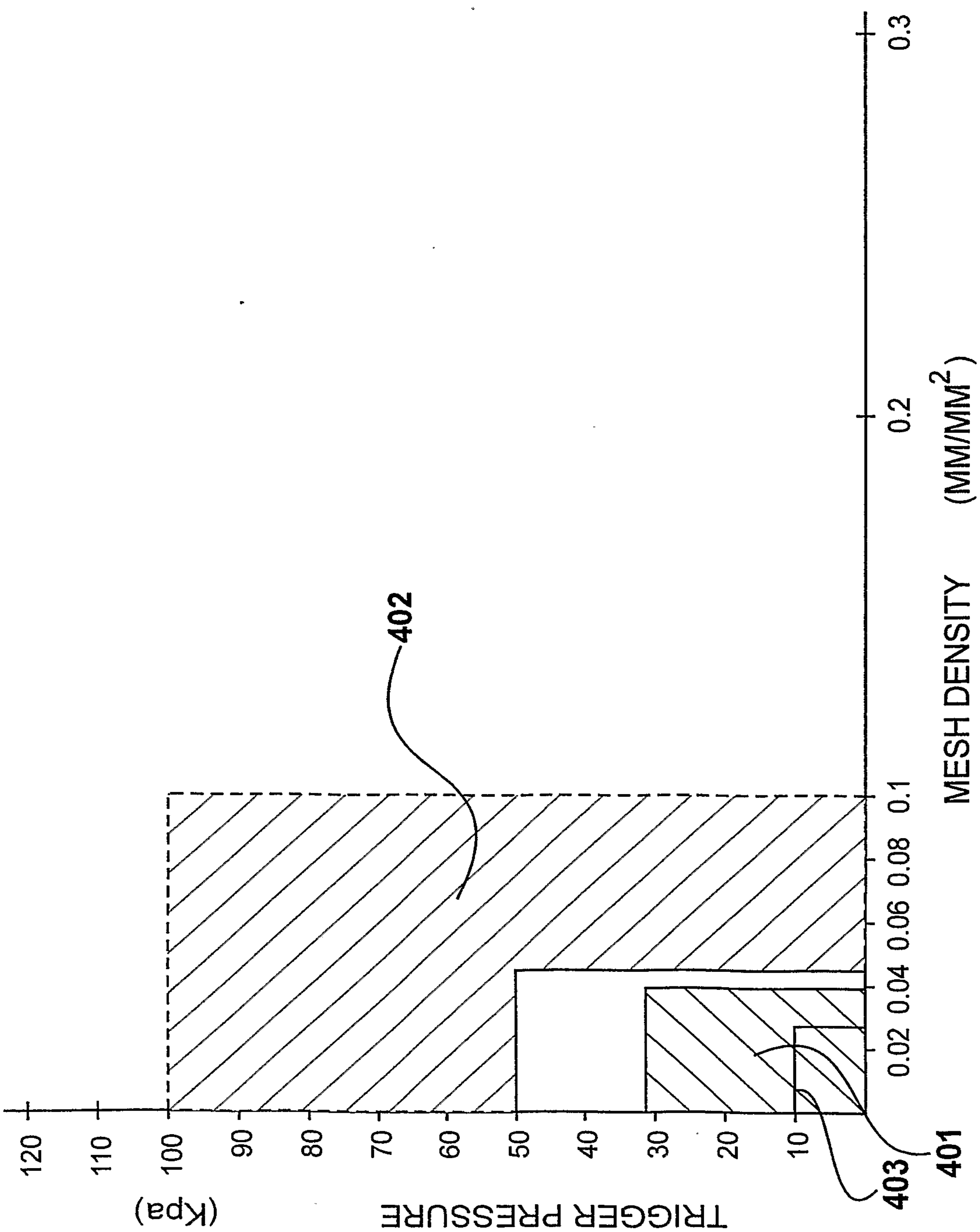

TRIGGER PRESSURE
(Kpa)
120
110
100
90
80
70
60
50
40
30
20
10
MESH DENSITY (MM/MM2)
0.02
0.04
0.06
0.08
0.1
0.2
0.3
401
402
403

*Figure 4*

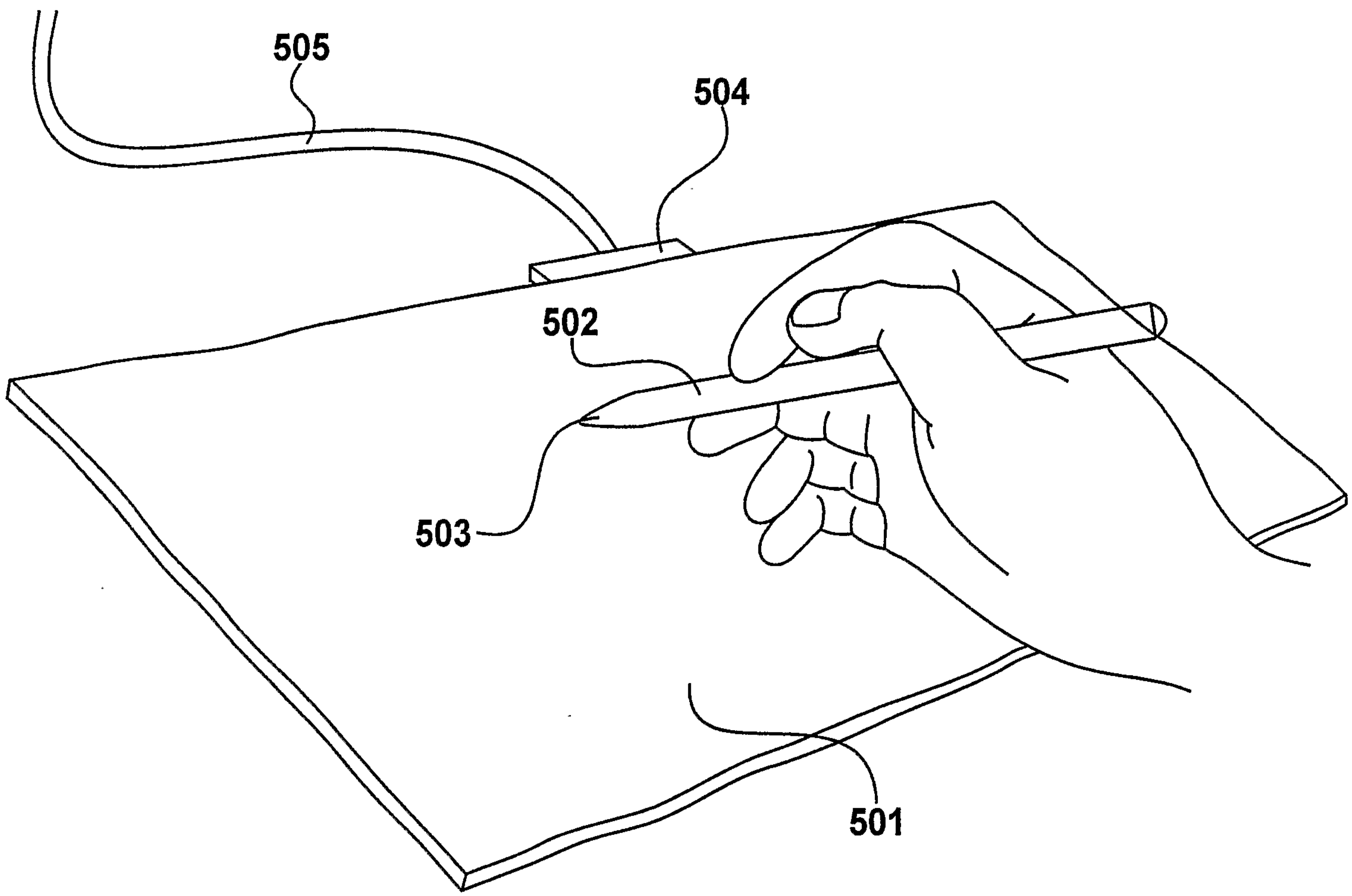



Figure 5

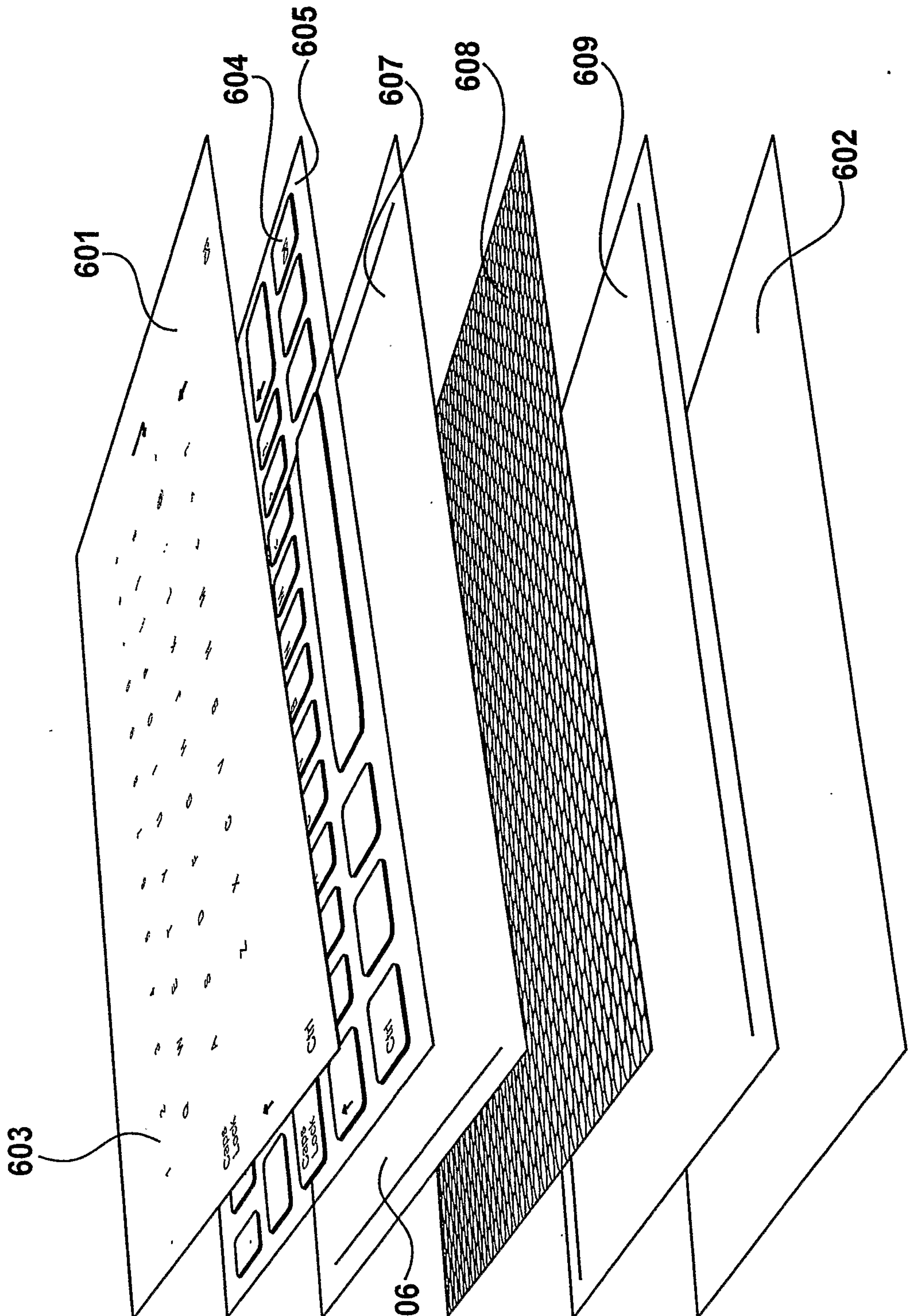

601
603
604
605
607
608
609
602
606
Caps Lock
Ctrl
Caps Lock
Ctrl

Figure 6

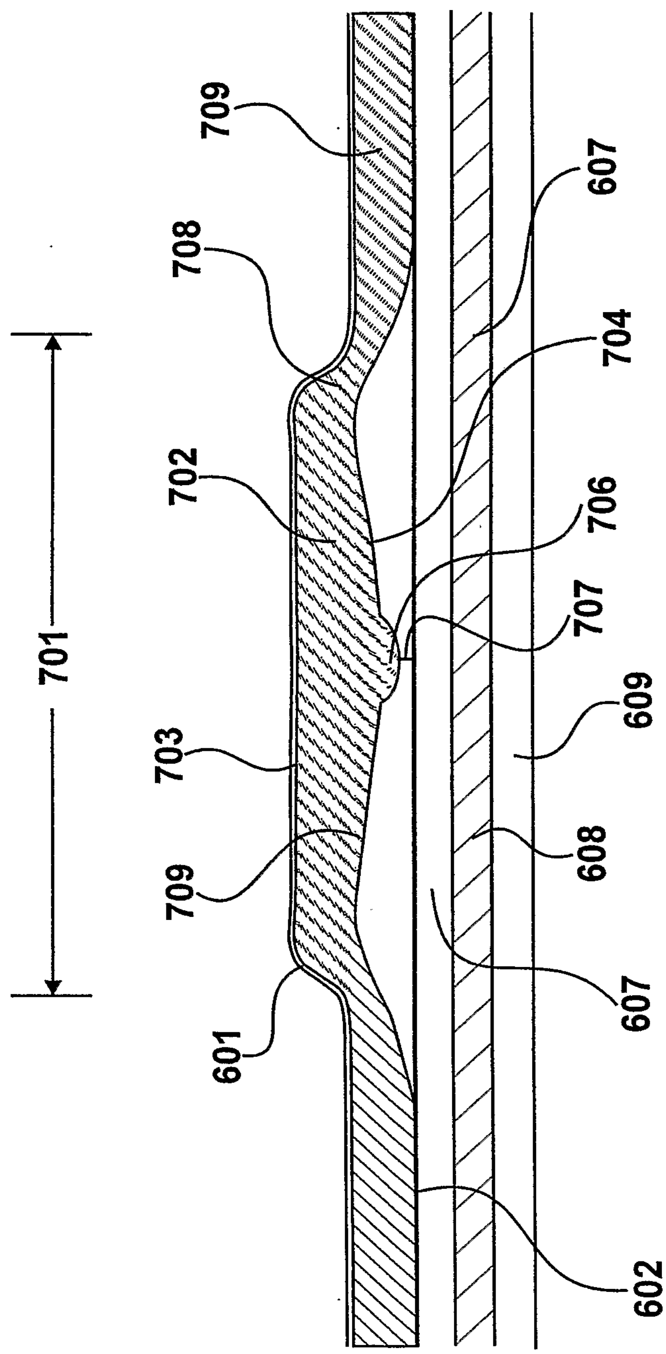



Figure 7

2040-P153-GB

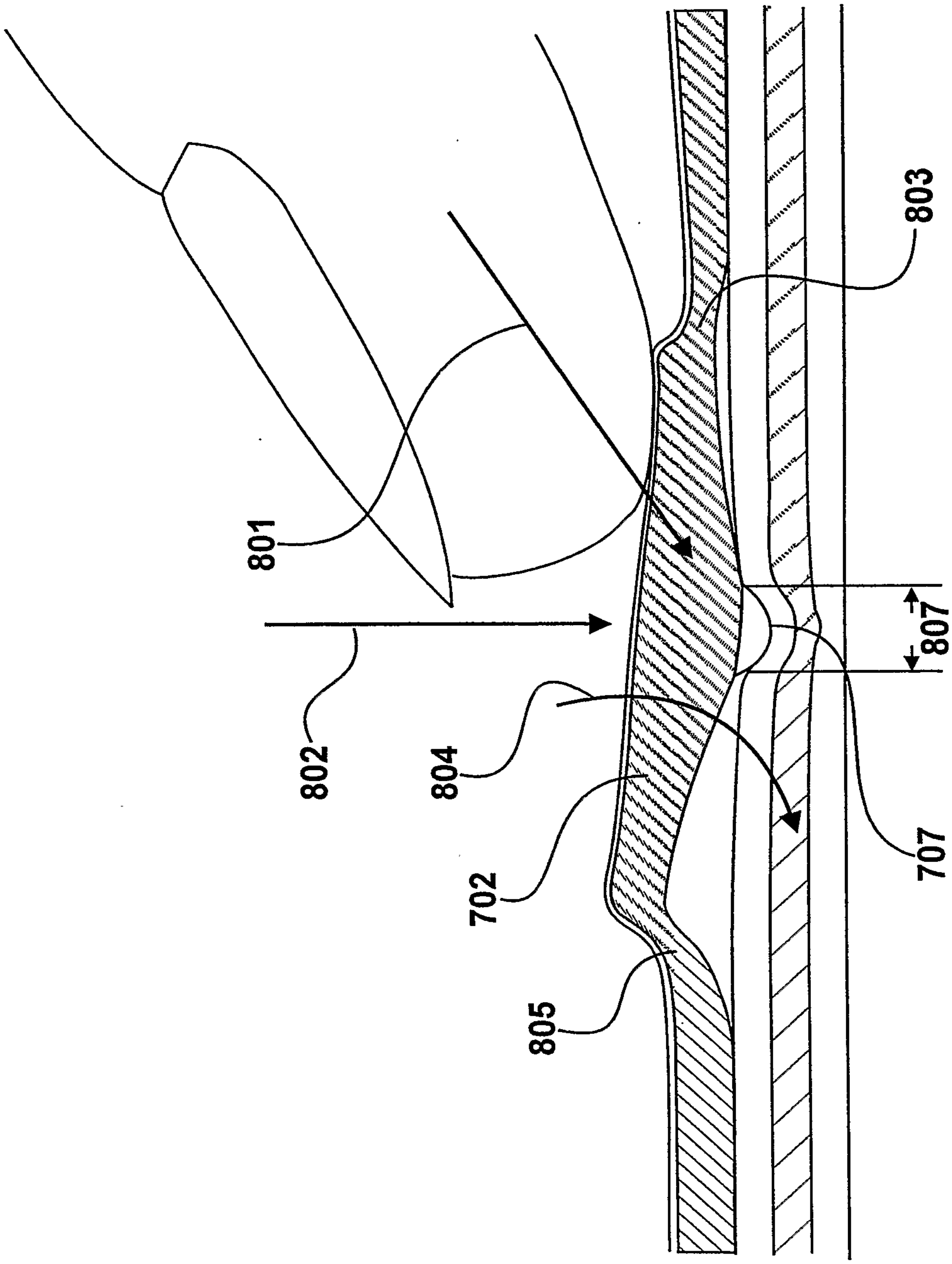



Figure 8

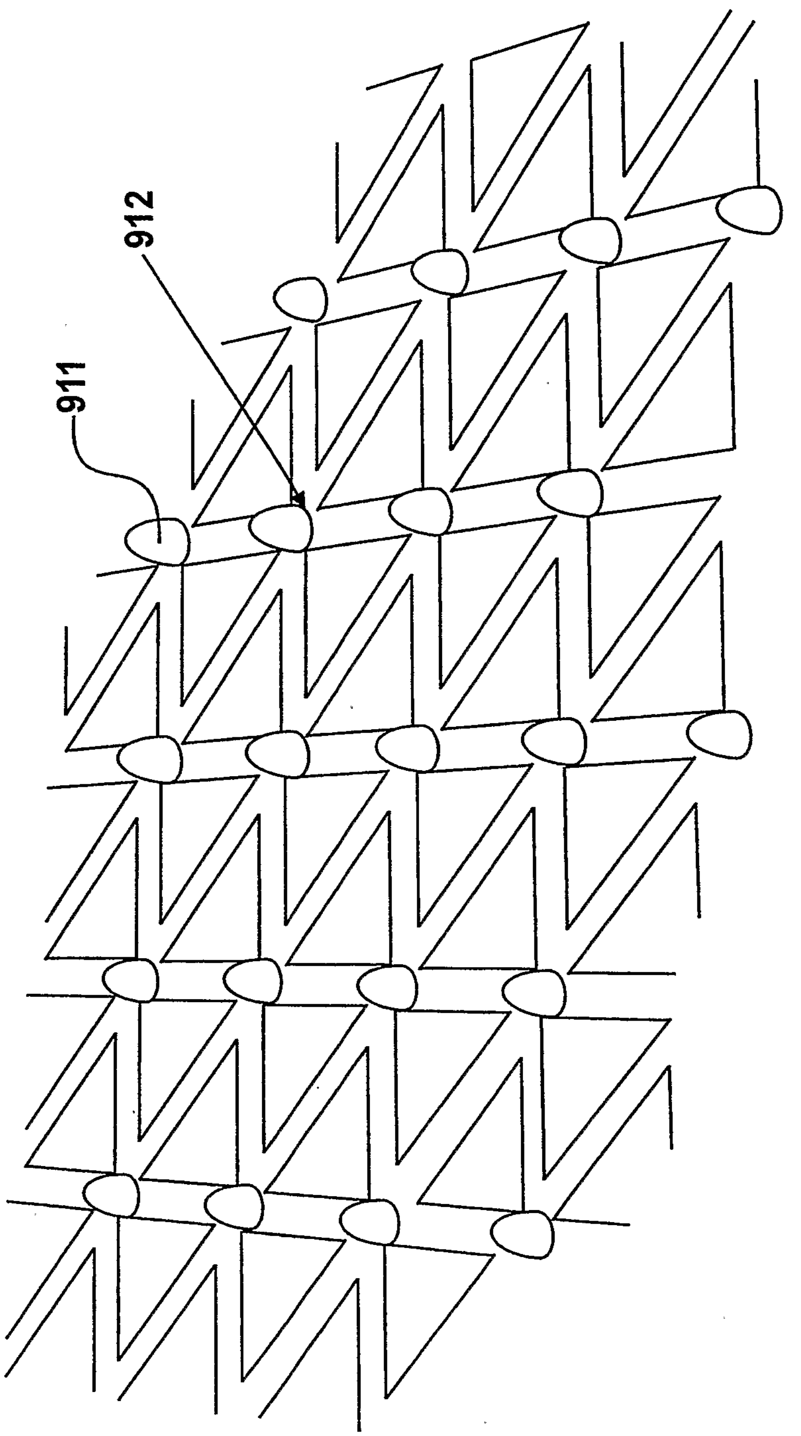
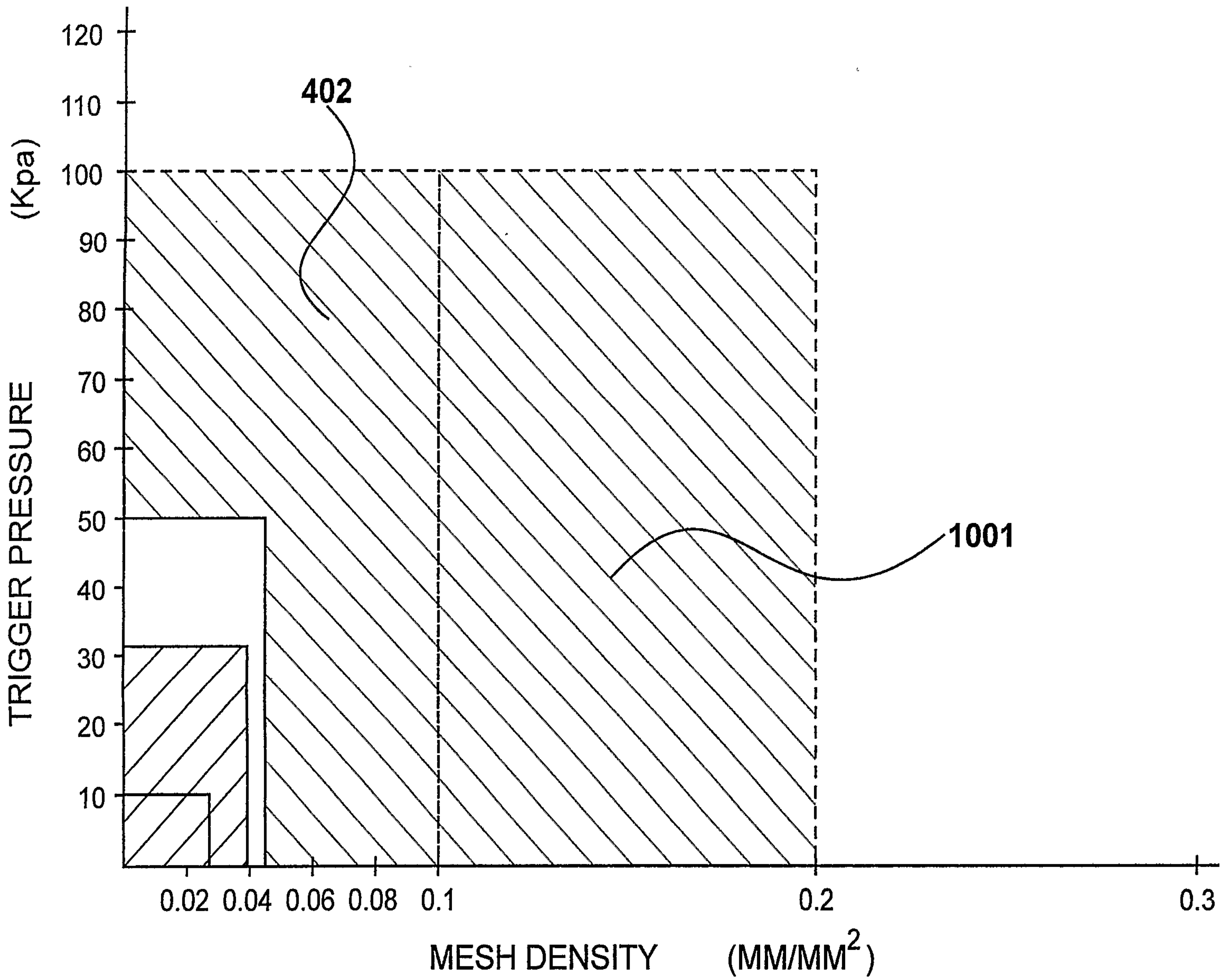



Figure 9



402
1001
120
110
100
90
80
70
60
50
40
30
20
10
TRIGGER PRESSURE (Kpa)
0.02 0.04 0.06 0.08 0.1
0.2
0.3
MESH DENSITY (MM/MM2)


Figure 10

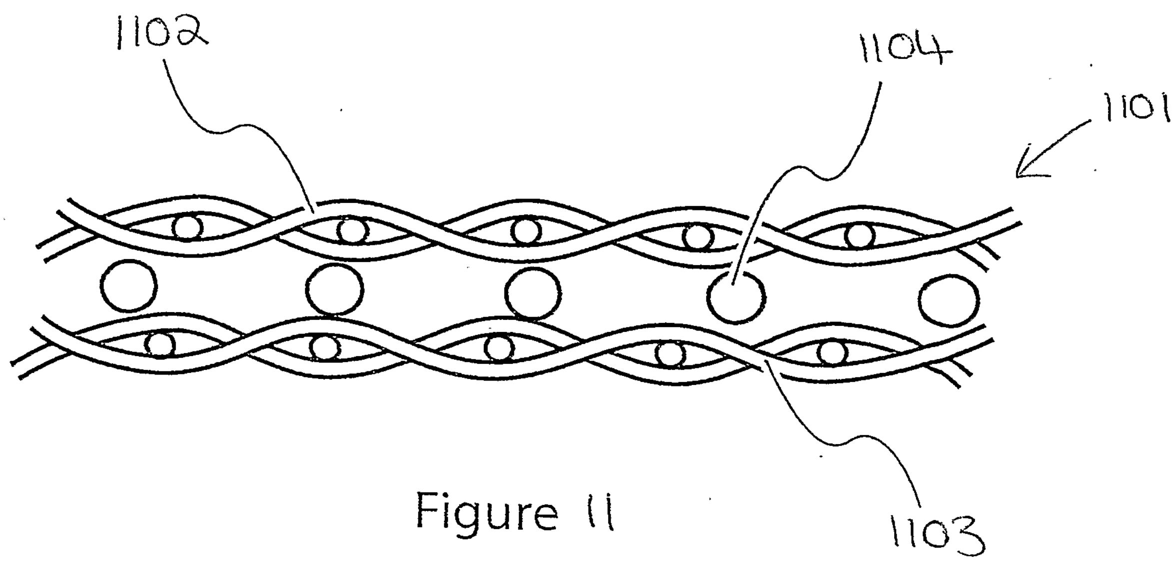



Figure 11

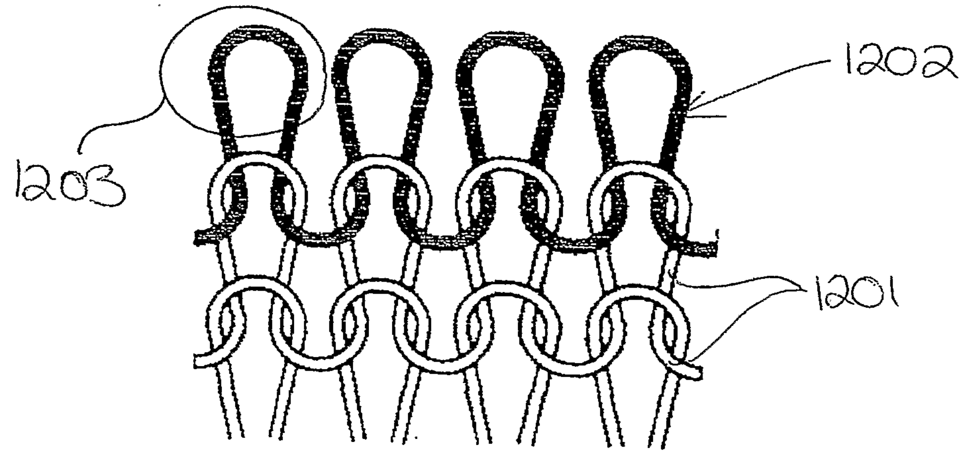



Figure 12

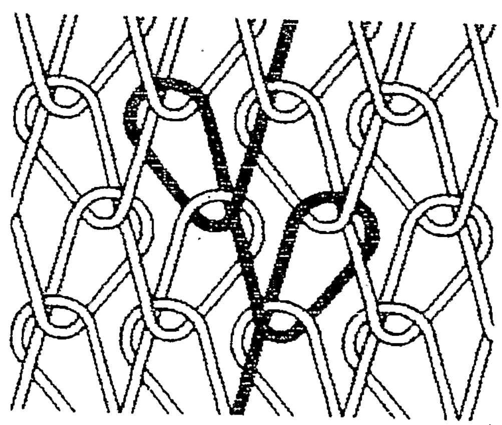


Figure 13

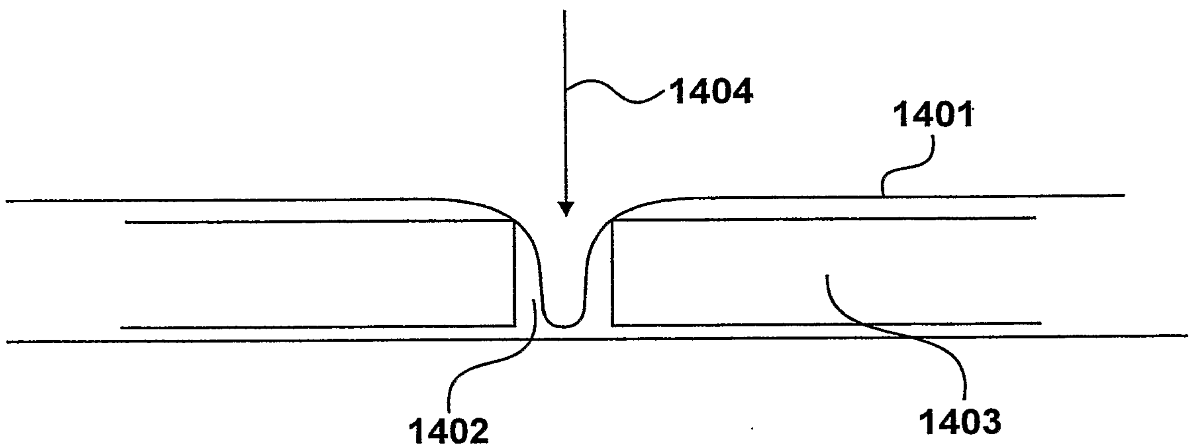



*Figure 14*

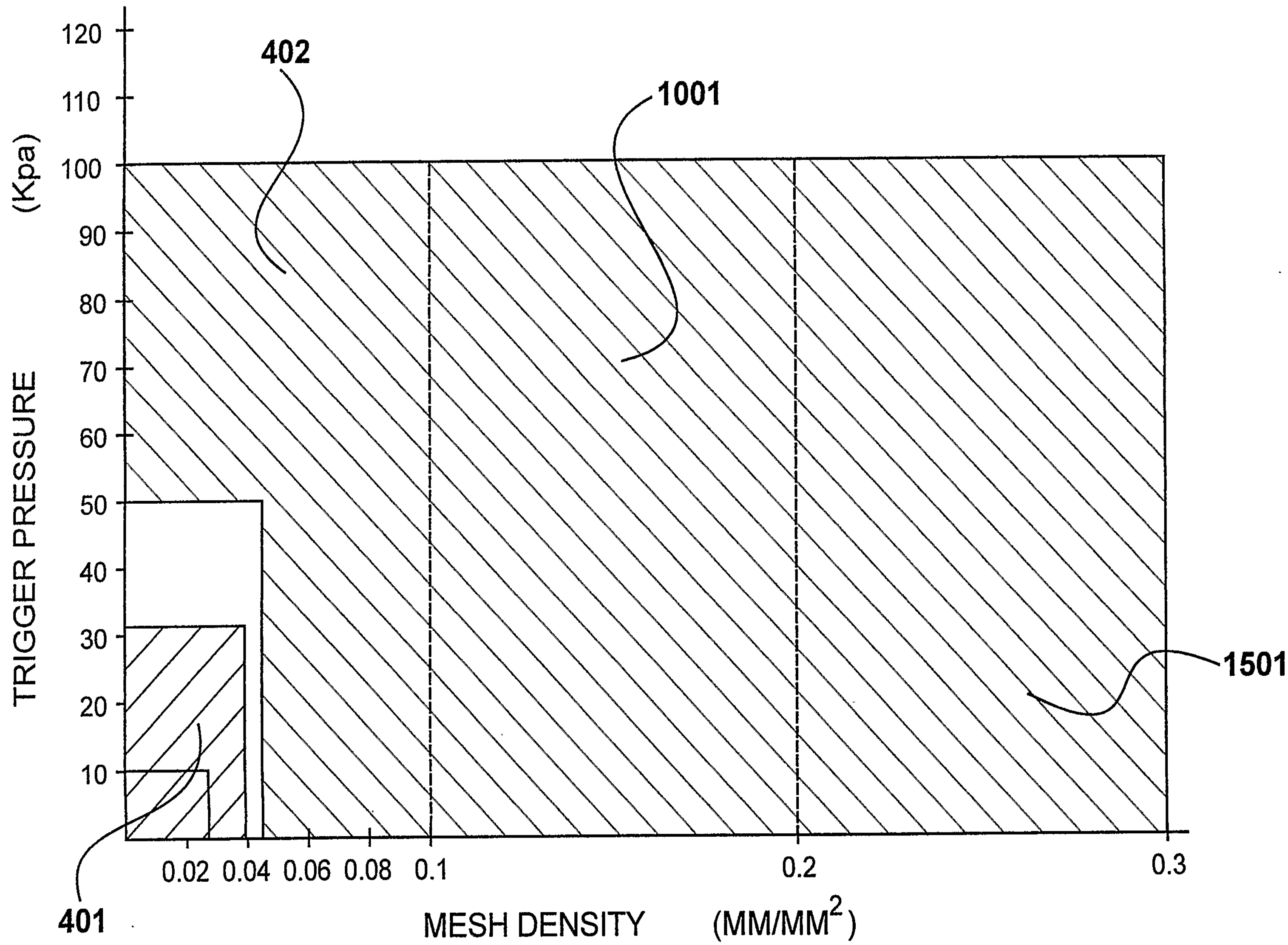

TRIGGER PRESSURE (Kpa)
120
110
100
90
80
70
60
50
40
30
20
10
0.02
0.04
0.06
0.08
0.1
0.2
0.3
MESH DENSITY (MM/MM²)
402
1001
1501
401

*Figure 15*

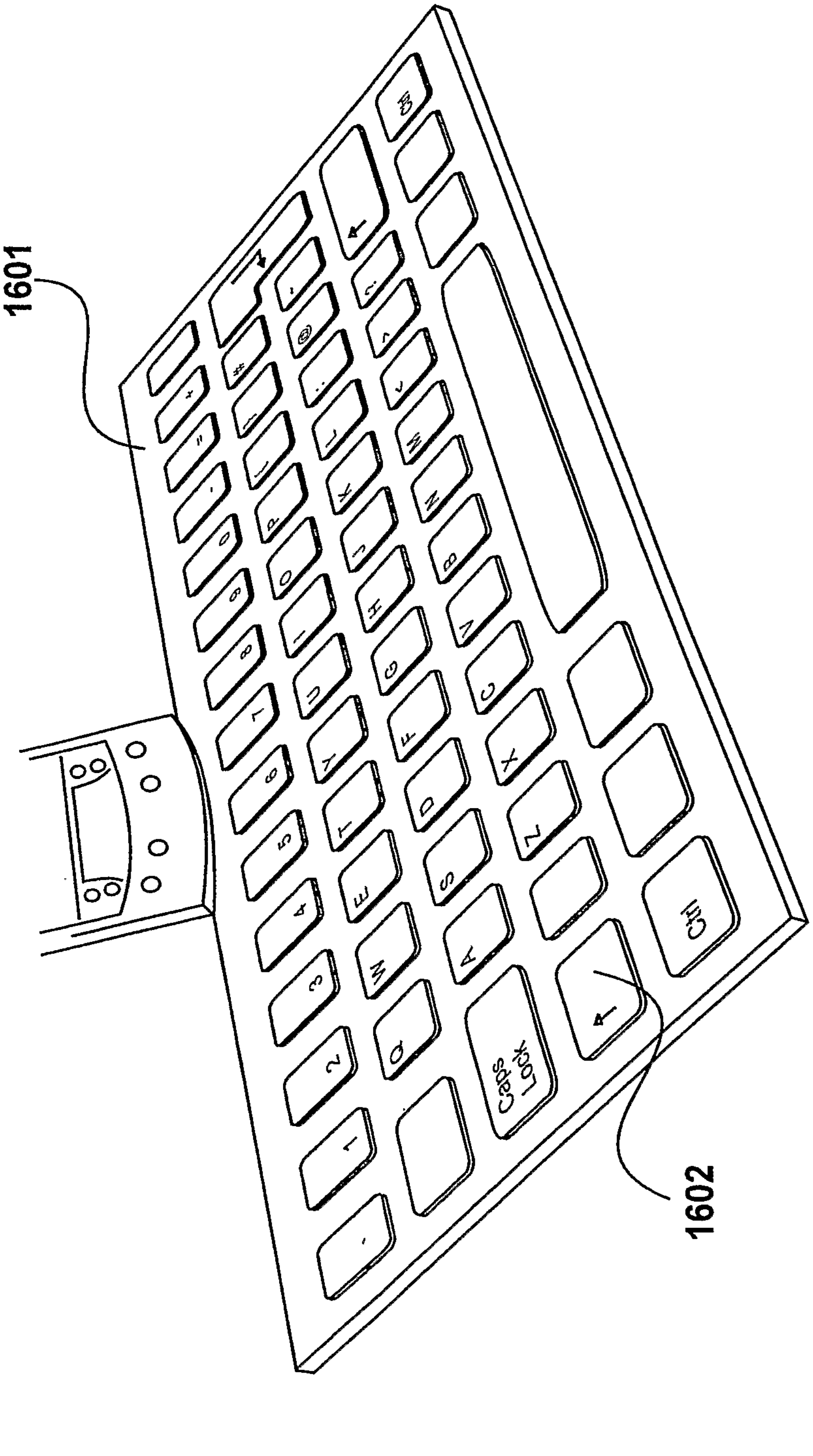



Figure 16

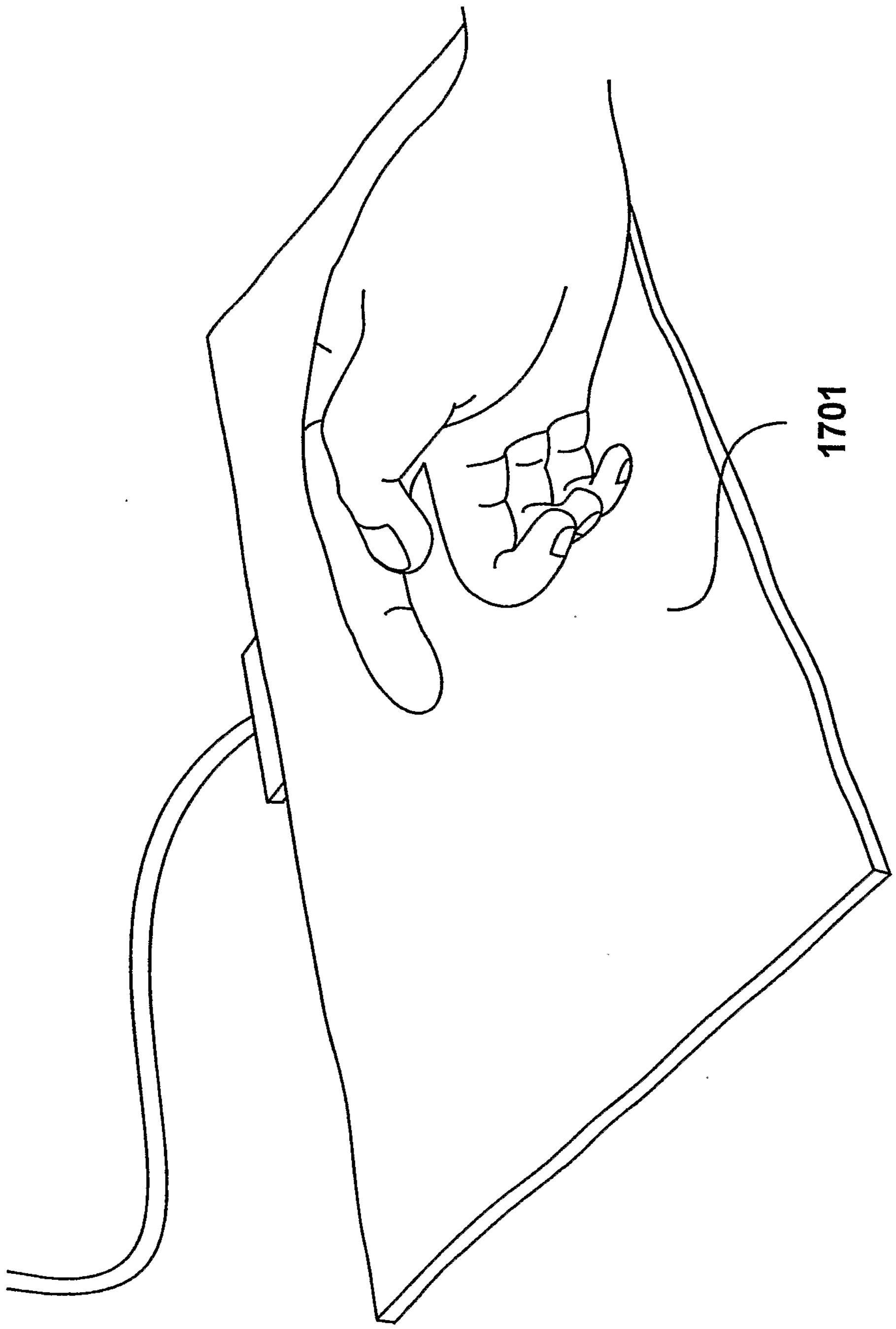



Figure 17

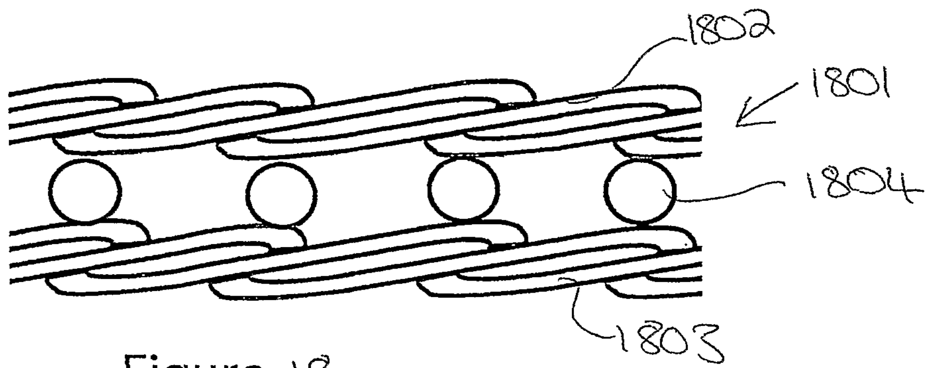



Figure 18

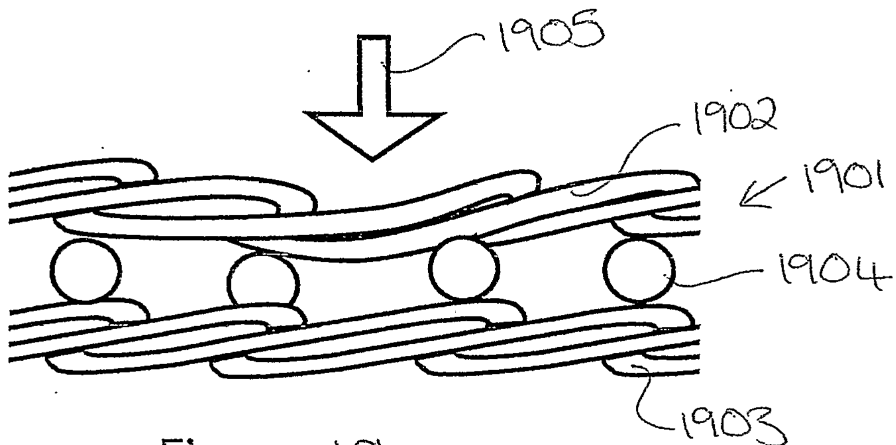



Figure 19

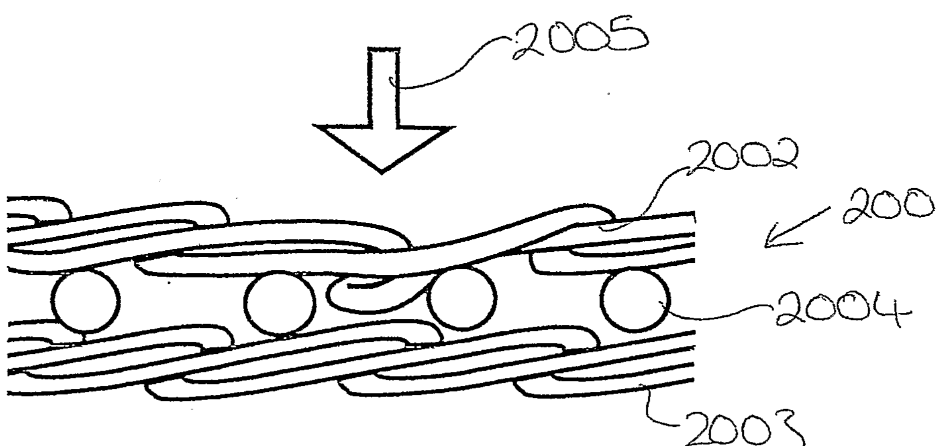



Figure 20

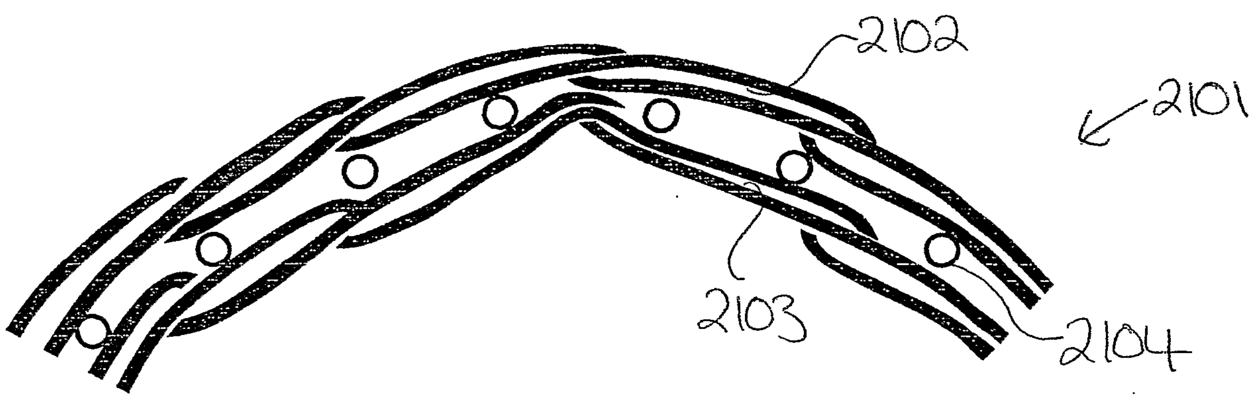



Figure 21

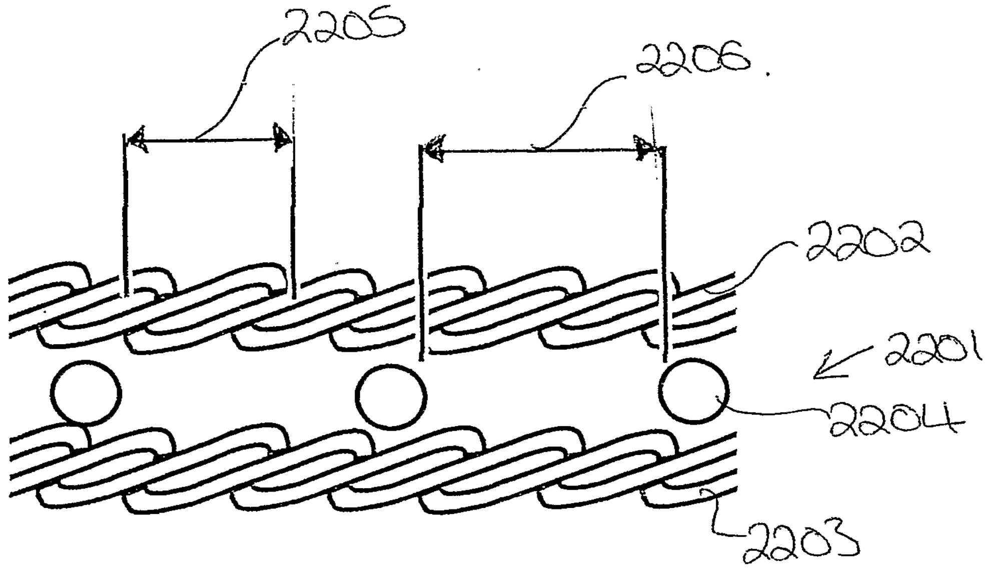



Figure 22

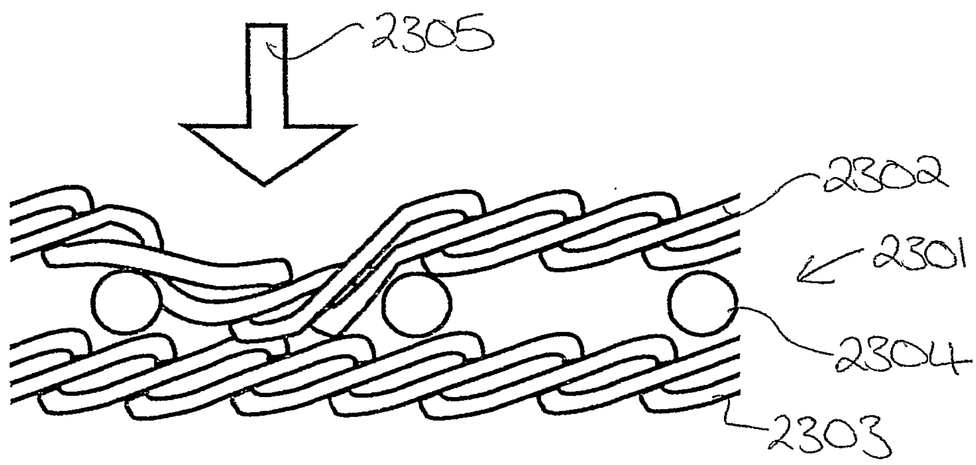



Figure 23

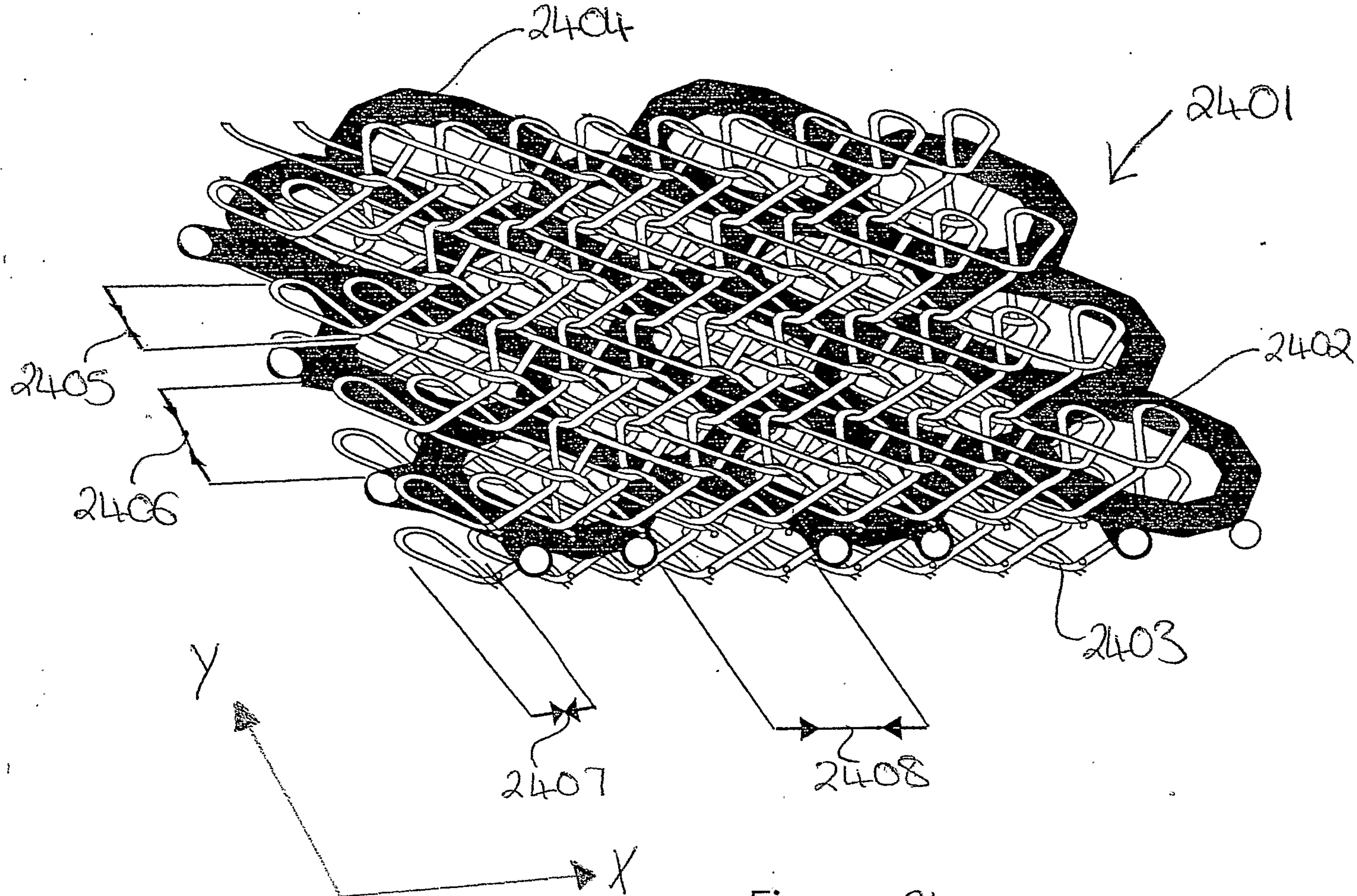



Figure 24

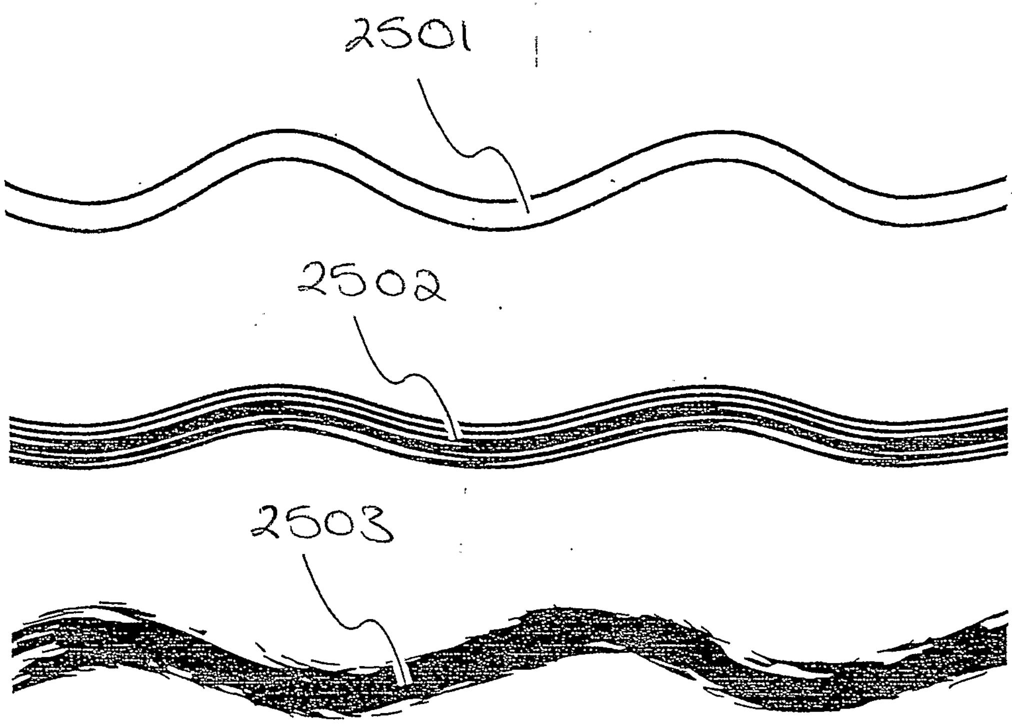



Figure 25

THE PATENT OFFICE
18 JUL 2005
Received in Patents
International Unit